

Variable-resolution ocean model improves physics at reduced computational cost

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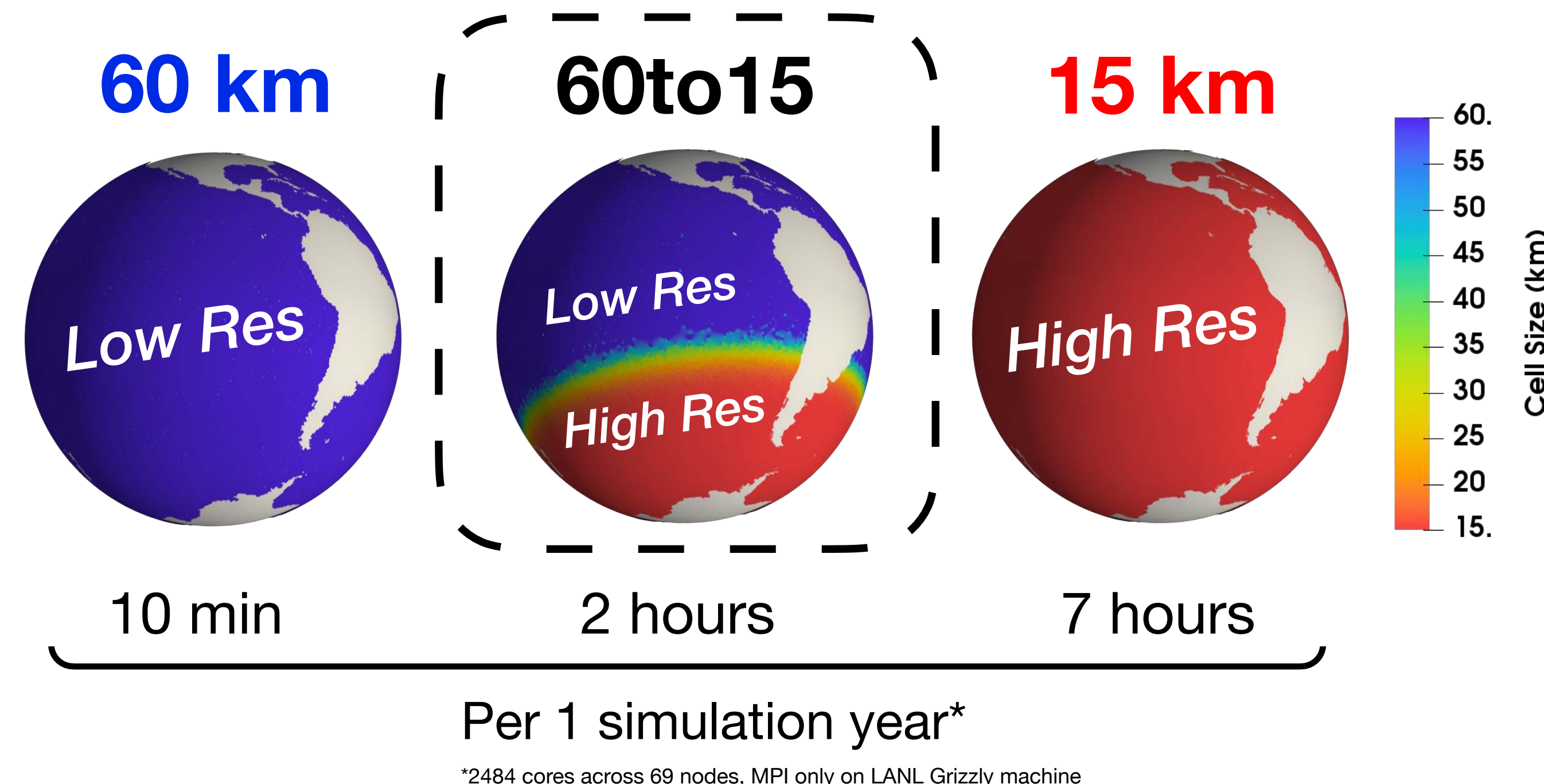
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Background and Motivation

- Climate models need finer spatial resolution to resolve important physics
- Currently, coupled global climate models use structured grids
 - *Very expensive to increase resolution: Resolution must be increased globally*
- MPAS-Ocean is the ocean component of a new DOE-developed climate modeling system, E3SM, which uses an unstructured horizontal mesh
 - *Ability to create enhanced high-resolution regions of interest within a global low-resolution mesh: Less expensive than increasing resolution globally*

Testing Variable-Resolution Mesh: The 3 Experiments



Why is it so expensive to run at 15 km resolution compared to 60 km?

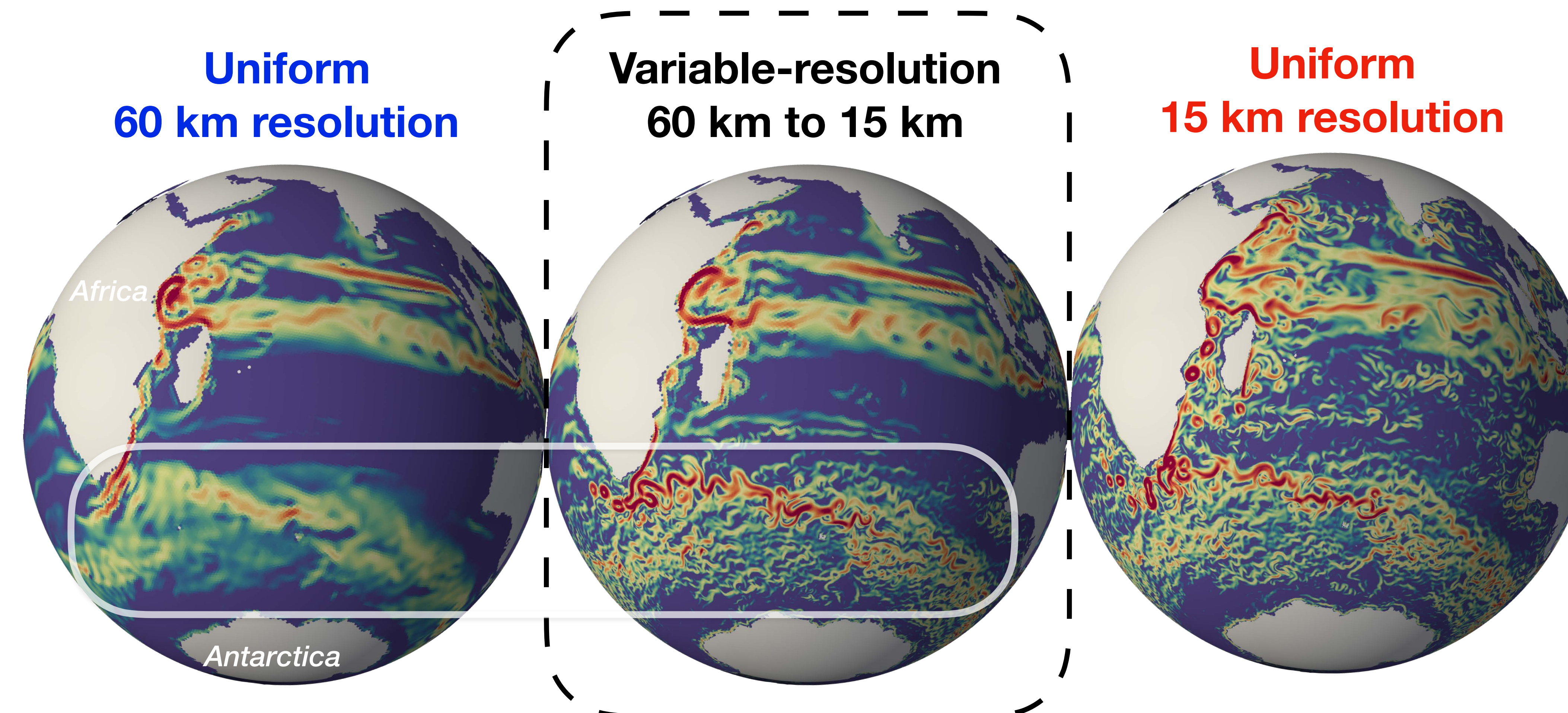
A model with 1/4 grid size will have 16x more grid cells and require 4x more timesteps per year, resulting in at least 64x longer runtime.

Acknowledgements

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Snapshots of surface current speed offer an intuitive picture of ocean eddies.

Eddies are important for the transport of heat, chemicals, and biological species. In coarse models, eddy effects must be **parameterized** since they are too small to be **resolved**.

The variable-resolution model above (middle frame) is eddy-permitting in the Southern Ocean and non-eddy-permitting everywhere else. The white box highlights the differences in the Southern Ocean between the “low-res” 60km model (left frame) and the variable-resolution model. Notice that this same region looks similar between the variable-resolution model and the “high-res” 15km model (right frame).

<< Take aways >>

- We present a method for validating the ocean component of a new variable-resolution coupled global climate model
- Case study: an enhanced-resolution region in the Southern Ocean
- Eddy Kinetic Energy (EKE) quantifies fine-scale variability and is used to validate that the enhanced-resolution region closely matches EKE from global high-res model
 - We added a new EKE calculation capability to the model’s automated analysis software *MPAS-Analysis* (github.com/MPAS-Dev/MPAS-Analysis)
- This grid-refinement technique can be applied to other high-energy regions (e.g. western boundary currents) to improve climate predictions

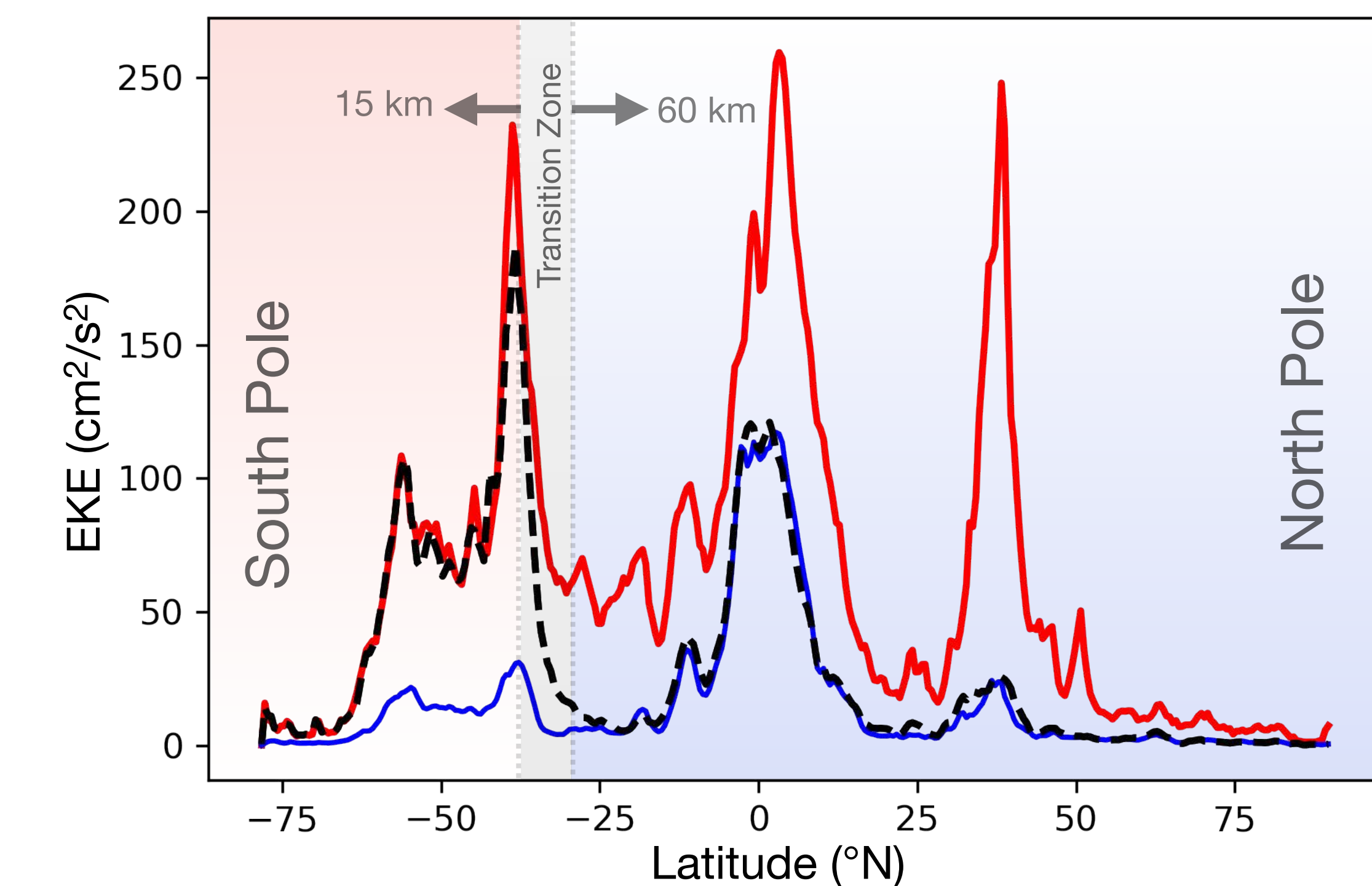
Defining Eddy Kinetic Energy

$$u = \bar{u} + u'$$

Ocean velocity Time-mean component Eddy, time-variable component

EKE is the Kinetic Energy associated with time-variable component of the velocity.
EKE = $\frac{1}{2} (u')^2$

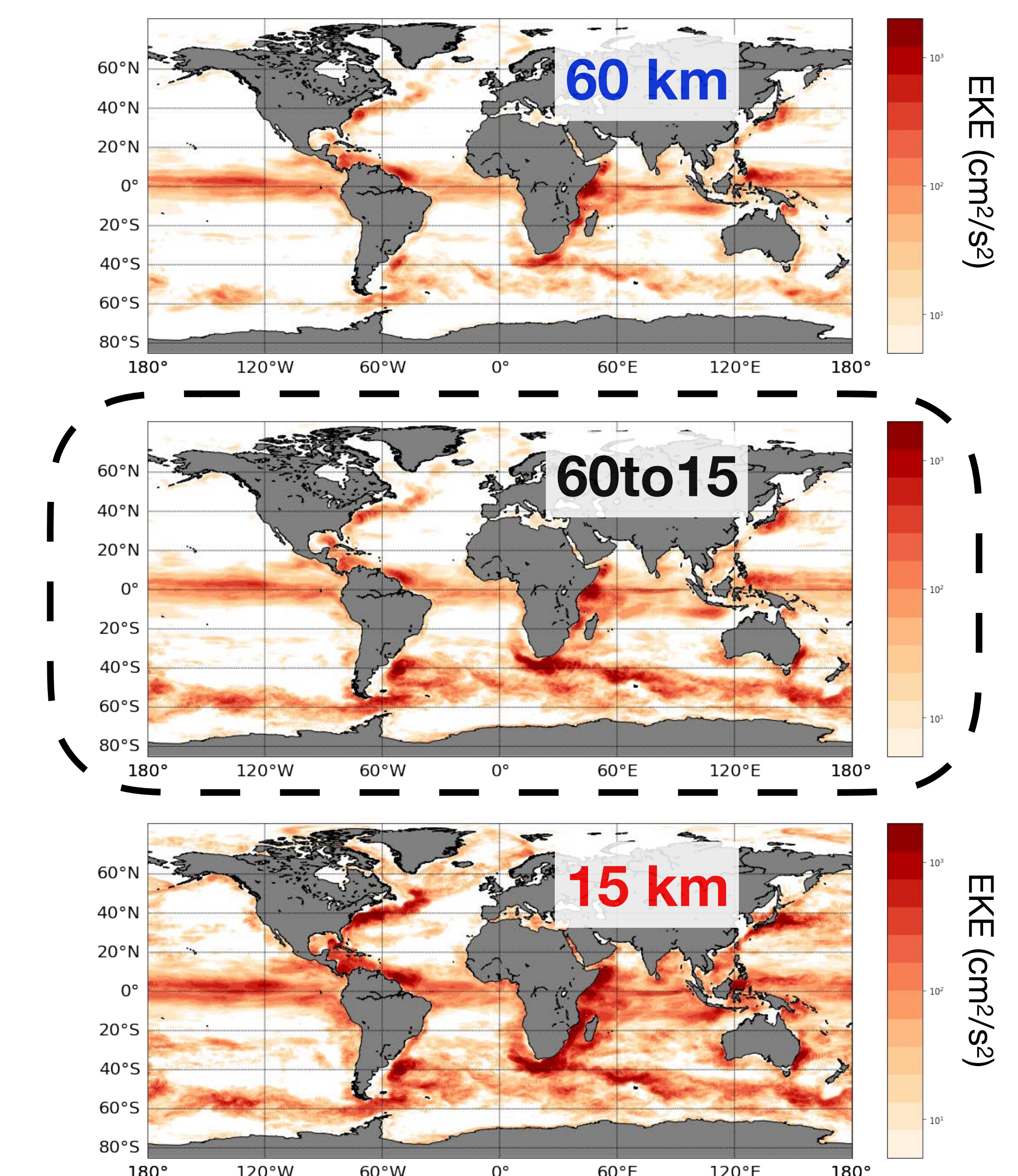
Zonal Mean Eddy Kinetic Energy



The **variable-resolution model (black dashed line)** matches the global **15 km model (red line)** in its 15km region and matches the global **60 km model (blue line)** in its 60 km region.

This result confirms our hypothesis. It shows that the variable-resolution approach can reproduce high-res results in the Southern Ocean without the computational expense of a global high-res model.

Eddy Kinetic Energy: Map View



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